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CSTF Evaporator Feed Qualification Program

Program Description Document

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Summary of Revisions

02/03 - Revision 0; Initial Issue

03/03 - Revision 1;

Revised Section 2.0 to clarify output documents general requirements; Clarified requirement 4.3.1.iii to exclude the drop tank; Included Sample Protocol reference; Clarified that the inadvertent transfer requirements apply only to HEU transfers.

03/04 - Revision 2;

Added technical basis to section 4.1 for evaporator bottoms hydrogen generation rate that shows that it is bounding and removed implementation action to verify through WCS; added interpretation to section 4.2 for 6 month requirement to determine NAS formation rate and silicon concentration; added discussion to 4.3 to state that 299-H material is no longer an accepted feed to the 2H system; added clarification to section 4.3 for monthly enrichment sample requirements and detailed action when samples are greater than 51 days old.; added clarification to section 4.3 concerning the 120 g monthly limit of U235 from the GPE; clarified that Tank 43 Flygt mixers have been electrically disconnected; other editorial changes highlighted with revision bars

1.0 SAFETY FUNCTION

The safety function of the Evaporator Feed Qualification Program is to ensure that the composition of waste streams received into the Evaporator feed tanks is within analyzed limits prior to transfer to the evaporator pot. Ensuring that the waste composition is within analyzed limits ensures that the assumptions made in the safety analysis are maintained.

2.0 PURPOSE

The purpose of this program description document is to provide background information and describe the key attributes of the Evaporator Feed Qualification Program.

The output documents generated by this Program Description Document (PDD) shall ensure independent verification or validation of results and conclusions. Output documents include, but are not limited to, calculations, procedures and technical reports.

Calculations issued as output documents shall be confirmed Type I calculations in accordance with the requirements of the E7 Manual, Procedure 2.31. Technical Reports issued as output documents shall comply with the requirements of E7 Manual, Procedure 3.60. Assumptions and recommendations from these reports shall be addressed in the Design Authority Technical Review (DATR) written against the Proposed Activity. Additionally, the output documents will be included in the USQ review process against the Proposed Activity per Manual 11Q, Procedure 1.05.

3.0 KEY ATTRIBUTES

The attributes of this program necessary to ensure that the assumptions made in the safety analysis are maintained are:

3.1 Hydrogen Generation Rate

The Evaporator Feed Qualification Program sets the hydrogen generation rate for the evaporator bottoms in order to keep the flammable vapors below the flammability levels in the vapor space.

3.2 Prevention of Sodium Aluminosilicate (NAS) Scale Formation in the 242-25H and 242-16F Evaporators

The Evaporator Feed Qualification Program prevents the formation of NAS scale in the 242-16F and 242-25H evaporators thus eliminating the criticality and flammability concerns caused by the adherent sodium diuranate.

3.3 242-16H Evaporator Enrichment and Flammability Control

The Evaporator Feed Qualification Program ensures that the total accumulated scale in the 242-16H evaporator is less than or equal to 200 gallons and evaporator feed enrichment is maintained such that evaporator pot criticality is not credible.

4.0 BACKGROUND/PROGRAM DESCRIPTION

The Evaporator Feed Qualification Program is included as a general control in Chapter 3 of the Documented Safety Analysis.[1] These general controls protect the general assumptions upon which the accident analysis calculations are based.

4.1 Attribute Requirement: Hydrogen Generation rate

Direct radiolytic hydrogen release to the vapor space is a primary contributor to total flammable vapor concentration in an evaporator pot and evaporator cell.[1] The radiolytic hydrogen release rate in the evaporator pot will be calculated using bounding generation rates for expected feed.

Hydrogen is produced in the tank farm waste by radiolysis of water. The hydrogen generation rate for a given waste depends on the radiation dose to the waste and the concentration of any hydrogen scavengers that serve to decrease the overall production of hydrogen.

4.1.1 Implementation Requirements and Background

The bounding radiolytic hydrogen generation rate for supernate and for evaporator bottoms (242-16F/16H and 242-25H) is 9.6E-6 ft^3/hr·gal.[1]

The current waste tank supernate inventory will meet the evaporator bottoms hydrogen generation limit for transfers into the 242-16F, 242-16H, and 242-25H evaporators. The established DSA limit was determined based on the bounding conditions for supernate and sludge coupled with an allowance for hydrogen scavenging (NOeff of 1.0 M).[2] These bounding conditions (including an allowance of 1 wt.% sludge solids in the evaporator bottoms) prevent the hydrogen generation from being exceeded due to evaporation.

The bounding hydrogen generation rate for evaporator bottoms is mainly due to the high Cs-137 content in the bounding supernate stream (with 1 wt% solids) designation.[2] This Cs-137 activity of 42 Ci/gal is twice the content of any waste tank (20.9 Ci/gal in Tank 36 is current maximum). The high salt content (13M sodium, 9.5 M hydroxide[3]) of this high Cs-137 activity waste prevents much additional concentration of that waste. Therefore, it is not credible that the Cs-137 content assumed for the bounding hydrogen generation can be exceeded.

The Corrosion Control Program[4] establishes the requirements for the corrosion prevention of the waste tanks and equipment by monitoring the concentration of the corrosive species present in the supernate. Therefore, nitrite and nitrate (hydrogen scavengers) sample data is available[5] in the Waste Characterization System (WCS).

An analysis of historical corrosion chemistry at high hydroxide concentrations has shown that a minimum NOeff of 1.55M is reasonable to use for flammability projections.[6] This provides some conservatism into the evaporator bottoms hydrogen generation rate limit since the empirical NOeff value of 1.55M is greater than the NOeff of 1.0M used to derive the limit. In addition, a calculation based on supernate concentrations in the waste tanks combined with a 1 wt% sludge composition in the evaporator feed tanks has shown all values to be below the evaporator bottoms hydrogen generation rate limit of 9.6E-6 ft^3/hr·gal.[7]

The Sludge Carryover Minimization Program[8] establishes the controls for the minimization of sludge solids carryover into the evaporator thus ensuring that the DSA assumptions are maintained.

The Waste Acceptance Criteria[9] for the Tank Farms verifies that influent waste streams will not cause the evaporator bottoms hydrogen generation rate to be exceeded when the incoming waste is sent directly to an evaporator feed tank or when it is combined with other tank farm waste awaiting for future processing (i.e., evaporation).

Due to the conservative assumptions (high Cs-137 content, low NOeff, 1wt% sludge) used in the DSA to derive the bounding evaporator bottoms hydrogen generation rate, there are no implementation actions required to protect the assumed limit.

4.1.2 Implementation Actions:

None

4.2 Attribute Requirement: Prevention of NAS Scale Formation in the 242-25H and 242-16F Evaporators

Typical high level waste contains large quantities of aluminum and small quantities of silicon, so relatively small changes in the silicon concentration result in significant changes in the expected formation rate of solids in the evaporators. Startup of DWPF Recycle stream introduced excess silicon into the waste tanks. When the high-silicon waste is used as evaporator feed, a mechanism exists to accumulate a hard scale composed of NAS. The scale decreases evaporator performance and presents a potential criticality safety concern due to the accumulation of fissile uranium with the NAS scale. Preventing the formation of NAS will eliminate the criticality concern caused by the uranium presence with the NAS scale in the 242-16F and 242-25H evaporator pots.

The DSA, Section 5.5.4.2.5 describes the necessary program to prevent NAS scale formation in the 242-16F or 242-25H Evaporators. The calculations to determine the NAS formation rate identified in the DSA are defined below. Implementation actions beyond that required by the DSA are also described.

4.2.1 NAS Formation Rate Calculation

The methodology for the calculating the NAS solid formation rate is based on the Gasteiger[10] approach. First, the solubility product (K_{sp}) is calculated using Equation 1, where I is the ionic strength and [OH] is the free hydroxide molar concentration:

Eq. #1

$$K_{sp} = \frac{\left(1.5\times10^{-4}\ \mathrm{M}^2\right)\times\left[OH^-\right]^3}{\left[I\right]^{1.6667}}$$

Then, the soluble silicon is calculated using Equation 2, where [Si] is in mg/l and [Al] is in molar units:

Eq. #2

$$\text{Soluble } [Si] = \frac{K_{sp}\times 28{,}000\,\text{mg/mol}}{[Al]}$$

Finally, Equation 3 estimates the amount of NAS that will precipitate after the 3x concentration by evaporation. This equation calculates the insoluble silicon concentration at a given concentration factor, normalizes this concentration to the starting volume, and converts to equivalent aluminosilicate quantity. Equation 3 calculates the mass of NAS produced by evaporating 1 liter of waste.

Eq. #3 $$mass_{NAS} = \left(\frac{Si_{total} - Si_{soluble}}{Si_{total}} \right) \times Si_{start} \times \frac{g\,NAS}{0.16\,g\,Si} \times \frac{g}{1000\,mg}$$

For simplification, the Na concentration is used as the ionic strength of the solution. Therefore, the concentration of carbonate, sulfate, oxalate and phosphate in the combined supernate shall be less than 0.5 M. In the event the concentration of these species is above 0.5M, the engineering evaluation will address the impacts to the ionic strength accordingly.

4.2.2 Implementation Actions:

1. Restricted waste tanks containing DWPF recycle or similar waste shall be listed in the ERD (N-ESR-G-00001).
2. The laboratory analysis for silicon concentration can be performed by either the filtration method or the acid strike method[11]. For the filtration method, the analytical lab will report the total silicon concentration adjusting for any filter loss during the analysis[12]. The sample protocol document describes the method for sample retrieval and analysis.[13]
3. The concentration of carbonate, sulfate, oxalate and phosphate in the supernate to be transferred into the evaporator system shall be less than 0.5 M. If the concentration of any of these is above 0.5M, a pre-transfer engineering evaluation will address the impacts to the ionic strength accordingly.
4. The DSA requires the silicon concentration and NAS formation rate to be determined every six months with a 25% extension allowance based on samples from the feed and drop tanks.[1] In order to satisfy this requirement, the NAS baseline calculation[14] is updated twice each year at six month intervals to incorporate the results of samples taken within the previous six months. The implementation of this part of the program includes the desired dates (during first 30 days of six month cycle) for samples to be taken so that there will be plenty of time to analyze the samples and allow for re-sampling if necessary, the required dates to satisfy the requirement that the sample be taken within the previous six months prior to issuance of the calculation, and the date the calculation is planned to be issued. Management signature for approval of the baseline calculation signifies completion of this requirement.[15]

4.3 Attribute Requirement: 242-16H Evaporator Enrichment and Flammability Control

A Nuclear Criticality Safety Evaluation[16] (NCSE) has been performed to evaluate the formation of NAS scale containing sodium diuranate in the 242-16H evaporator pot. This Program Description Document addresses the implementation of the programmatic requirements specified in the NCSE and, as such, shall be considered the 242-16H

Evaporator Enrichment Control Program. The 242-16H evaporator pot flammability controls are also addressed.

4.3.1 Implementation Requirements and Actions

1. The nominal supernate enrichment of the 242-16H evaporator feed shall be less than an U^{235} enrichment of 1.1% relative to U^{238} (abbreviated U(1.1)) under normal operations. This is accomplished by monitoring the influents into Tank Farm and into the 242-16H evaporator feed and drop tanks (Tanks 43 and 38, respectively). See the following steps for specific actions.

   - The supernate enrichments of DWPF recycle shall be less than or equal to U(0.7). RBOF waste, and Tank Farm waste tanks storing influent waste streams for future processing through the 242-16H evaporator system (Tanks 6, 21, 22, 23, and 24) shall be less than the target supernate enrichment of U(0.7). This provides a high volume dilution into the 242-16H evaporator system to offset the small volume enriched streams, thus maintaining the overall enrichment < U(1.1).

      i. The Waste Acceptance Criteria Program shall verify DWPF recycle U enrichment is less than or equal to U(0.7).

      ii. Tanks 6, 21, 22, 23, and 24 shall be verified less than U(0.7) via annual sampling. The sample protocol document describes the method for sample retrieval and analysis.[13]

      iii. Waste tank (other than the drop tank) to feed tank (Tank 43) transfers shall be verified less than U(0.7) via the SW11.1-WTS procedure.

   - H-Canyon General Purpose Evaporator (GPE) waste transfers to Tank 43 shall not exceed 120 grams of Highly Enriched Uranium (HEU) per month. The NCSE calculations[16] clearly show that the GPE receipts have been analyzed based on a maximum of 120 grams of fissile U-235 per month. Therefore, monitoring the U-235 content of the GPE waste satisfies the NCSE requirements for 120 g HEU per month.

      i. The Waste Acceptance Criteria Program shall verify H-Canyon GPE evaporator waste transfers to Tank 43 do not exceed 120 grams of fissile U-235 per month.

   - Transfers of HEU supernate from HPT-7 to Tank 38 shall be less than or equal to 2,650 gallons per month.

      i. The transfer procedure shall verify HPT-7 transfers to Tank 38 are less than or equal to 2,650 gallons per month.

   - Transfers of HEU supernate from HPT-2 and HPT-3 to Tank 38 shall be less than or equal to 3,510 gallons per month.

      i. The transfer procedure shall verify HPT-2 and HPT-3 transfers to Tank 38 are less than or equal to 3,510 gallons per month, combined.

- Waste transfers from the 299-H facility waste shall contain small quantities of uranium (typically less than 15 grams) and an uranium enrichment less than U(1.1). The 299-H facility shall require that items entering the facility be drained or flushed and rinsed.

    i. The 299-H Waste Acceptance Criteria[17] shall verify items entering the facility are drained or flushed and rinsed.

    ii. The Waste Acceptance Criteria Program shall verify waste transfers to the Tank Farm contain on average 15 grams of uranium or less, and the uranium enrichment is less than U(1.1). This requirement only applies to transfers from 299-H to Tank 43 and Tank 38. Recent samples taken from 299-H showed an enrichment of greater than U(1.1). Therefore, a Nuclear Criticality Safety Analysis was written to document that recent additions with high enrichment from 299-H did not increase the uranium enrichment in the 2H system based on the small volumes and low concentration of uranium in the 299-H waste.[18] However, the 299-H waste was recommended to be removed from the list of allowed influents into the 2H Evaporator system (Tank 38 or 43) since it was outside of the 2H NCSE assumptions. Waste from 299-H shall not be transferred directly to the 2H Evaporator feed and drop tanks. After the 299-H waste has been transferred out of H Pump Tank 5, no flushing is needed to restore the enrichment or reduce the mass so that the General Purpose Evaporator (GPE) bottoms can be received into Tank 43 since the assumed enrichment for GPE bottoms is a bounding U(66)[16] and the concentration of fissile uranium in 299-H waste is low.[18]

- HEU waste transfers except those listed above into Tanks 38 or 43 are prohibited.

- Routine sampling of Tank 38 and Tank 43 shall be performed to monitor the enrichment.

    i. Samples of Tanks 38 and 43 shall be pulled monthly. The intent of monthly is that the samples will be pulled at least once every 30 days. The sample protocol document describes the method for sample retrieval and analysis.[13] The sample analysis results are required to be approved by the Data Integrity Review Team (DIRT) within 21 days after the sample pull date, which allows the lab sufficient time to analyze the sample and forward the results to DIRT. The combination of the 30 day sample frequency and 21 days for analysis and approval by DIRT ensures that the sample results are less than or equal to 51 days old. DIRT meetings are conducted by the Waste Characterization Cognizant Function to validate sample results. DIRT meeting minutes are recorded to document approval of the sample results. This approval of the enrichment results will be communicated to facility operations management. Operations maintain a status board with the enrichment results. This represents a satisfactory method to track the results as long as the results have been approved by DIRT. The results of the enrichment samples are periodically updated in the Emergency Response Document (ERD) after DIRT approval.[19]

ii. If the sample analysis results are ≥ U(1.1), or if the sample analysis results are > U(0.8) for 4 consecutive months; then the 242-16H evaporator feed pump must be secured, recycle transfers shall be terminated, and an engineering evaluation performed to restore the enrichment as prescribed by the NCSE.

iii. If the latest approved enrichment sample results for Tank 43 are greater than 51 days old based on the approved sample pull date, then the 2H evaporator shall be shut down until new sample results are approved. If the latest approved enrichment sample results are greater than 51 days old for Tank 38 based on the approved sample pull date, then recycle transfers shall be secured until new sample results are approved.

iv. If an enrichment sample for Tank 43 has not been taken in the last 30 days, then the 2H Evaporator shall be shut down until a new sample is pulled. If an enrichment sample for Tank 38 has not been taken in the last 30 days, then recycle transfers shall be secured until a new sample is pulled.

2. Waste transfer operations shall be monitored to ensure sludge solids are not disturbed in Tank 43 and inadvertent transfers into Tanks 38 or 43 are precluded.

- All influent waste streams into Tank 43H shall be greater than or equal to 36 inches above the settled sludge surface.

  i. This requirement is implemented through the Sludge Carryover Minimization Program.[8]

- The Tank 43 evaporator feed pump recycle discharge line shall be greater than or equal to 24 inches above the settled sludge surface.

  i. This requirement is implemented through the Sludge Carryover Minimization Program.[8]

- Tank 43 Flygt mixers shall be de-energized while evaporator feed pump is operating.

  i. The Tank 43 Flygt mixers have been electrically disconnected. Restoring the power supply and reconnecting the wiring to the Flygt mixers or adding a new mixing device would result in the need to add a step to verify that mixing devices are de-energized prior to evaporator feed pump operation per SW9.2-IOP-EVAP procedure.

- If Tank 38 or Tank 43 is monitored during a transfer for transfer events per the Transfer Control Program[20], then the cumulative inadvertent HEU transfer volume into both tanks shall be less than 4,900 gallons per transfer. In the event the cumulative inadvertent HEU transfer volume is greater than 4,900 gallons, feed to the evaporator shall be stopped and an evaluation performed to determined impacts to the enrichment in the feed. If a leak check and administrative lock of an isolation valve between the Transfer Path to the monitored tank (Tank 38 and/or Tank 43) is conducted prior to the transfer, then monitoring for the 4,900 gallon inadvertent HEU transfer is not required.

i. This requirement is implemented via the specific transfer procedures.

- Monitoring for an inadvertent HEU transfer shall be conducted within the first hour after the waste transfer is initiated.

  i. This requirement is implemented through the Transfer Control Program.

3. 242-16H evaporator operation shall be monitored on a routine basis to assess for scale buildup in the evaporator pot.

   - A siphon flow check shall be conducted after every 2,160 hours of operation. If the flow has deteriorated to less than 50% of the baseline flow and can not be restored, then an engineering evaluation is required prior to evaporator operation.

     i. This requirement is implemented via operating procedures.

   - The evaporator pot shall be visually inspected after every 4,320 hours of operation. The scale volume shall be determined[21] and verified less than 200 gallons[1] to protect evaporator pot flammability.

     i. This requirement is implemented via operating procedures.

4. CST Operations and Engineering will perform and assess core samples of Tank 38 salt layer as required by Tank 38 Criticality Assessment.[22]

   - Tank 38 salt is critically safe based on the areal density of the fissile material.[23] Therefore, this item requires no further action for implementation.

5.0 REFERENCES

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[14] X-CLC-G-00026, Sodium Aluminosilicate Baseline Formation Rate Calculations for 2F and 3H Evaporators

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[18] WSRC-TR-2004-00068, Nuclear Criticality Safety Assessment: 299-H Facility HEU Transfers to 242-16H Evaporator, D.A. Eghbali, March 2004

[19] N-ESR-G-00001, High Level Waste Emergency Response Data and Waste Tank Data

[20] WSRC-TR-2002-00403, Tank Farm Transfer Control Program & Pump Tank Transfer Jet Control Program, N. R. Pasala

[21] X-CLC-H-00218, Rev. 0, Volume of Scale in the 242-16H Evaporator, D. C. Bumgardner

[22] WSRC-TR-96-00336, Rev. 3, Nuclear Criticality Safety Assessment for Tank 38H Salt Dissolution, M.D. Murray

[23] G-USQ-H-01008, Closure of Tank 38H PISA, G. J. Hutchens